

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of

Modifying Emission Limits in the 24.25-
24.45 and 24.75-25.25 GHz Bands

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ET Docket No. 21-186

**COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES**

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF),¹ hereby submits its Comments in response to the Commission's Notice of Proposed Rulemaking (FCC 23-114, released December 22, 2023) in the above-captioned docket ("NPRM"). In these Comments, CORF outlines the passive scientific use of the 23.6-24.0 GHz band, as well as the application of out-of-band emission ("OOBE") limits necessary to protect such uses.

I. Introduction: Earth Exploration Satellite Service/Earth Remote Sensing and Radio Astronomy at 24 GHz and the Unique Vulnerability of Passive Services to Interference.

Paragraph 1 of the NPRM explicitly states the need to "facilitate the protection of passive sensors used for weather forecasting and scientific research in the 23.6 GHz-24.0 GHz band." CORF acknowledges the Commission's recognition of the critical importance of protecting this band, which is reserved for passive scientific use, from operations in the neighboring 24.25-24.45 GHz and 24.75-25.25 GHz bands in the

¹ See the Appendix for the membership of the Committee on Radio Frequencies ("CORF").

Upper Microwave Flexible Use Service (“UMFUS”). These passive scientific uses are highly vulnerable to interference, and their public interest benefits have long been recognized by the Commission.

Observations made by Earth Exploration Satellite Service (“EESS”) sensors provide unique data regarding the state of the Earth System, and especially its atmosphere at a given moment in time, which, by their very nature, cannot be reproduced or replicated. The observation frequencies cannot be modified, because they are largely determined by the physical characteristics of what needs to be observed—for example, specific water vapor lines are the result of the molecular properties of water. At microwave frequencies, the amount of radiation received by these EESS sensors is exceedingly small (see discussion in Section II, below, for quantification), and consequently these sensors have to be extremely sensitive. To provide data with sufficient fidelity for accurate weather forecasts and scientific research, great care is needed to ensure that the observations remain free from any spurious radiation that might contaminate the measurements. In the present congested radio frequency (“RF”) environment, observations consistent with radio frequency interference (“RFI”) contamination are already found internationally in the protected 23.6-24.0 GHz band (see Figure 1), anticipating the possible consequences of wide U.S. deployment of transmitters in neighboring bands envisioned by the Commission in future years. The reason that EESS observations are sensitive to multiple small RFI sources is that they view wide areas of Earth’s surface from diverse directions, covering the whole Earth multiple times per day. This is in contrast with fixed-point radio astronomy observations, for which location-specific protections can be effective.



FIGURE 1: Example of emissions within the 23.6-24.0 GHz band consistent with radio frequency interference contamination in Turkey. Counts of AMSR2 23.8 GHz (vertically polarized channel) radiances >310 K during 2022, indicating low emission levels in blue, medium levels in green, and high levels in red. SOURCE: Committee generated

Table 1 lists selected current and planned EESS passive sensors observing in the 23.6-24.0 GHz band.² As discussed in the prior CORF filing in this proceeding, these measurements are central for operational weather forecasting and essential for numerous other meteorological applications. In addition to points raised in its prior filing,

² Table 1 includes select satellites/instruments operated or to be operated by NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Defense, along with those from their European, Indian, and Japanese counterparts. Other countries operate additional satellites that observe data in the United States, which are important to weather forecasting and climate science. All of these microwave sensors are in a low Earth orbit (primarily polar), and any given satellite/sensor will, at best, provide global coverage twice per day. The goal is to have at least a 4-6 hour revisit time to observe the same point on Earth by a satellite observing the same or similar weather information. The current 4-6 hour revisit rate is achieved through the shared use of satellite observations provided by multiple space agencies. These observations are distributed as part of the World Meteorological Organization (WMO) Integrated Global Observing System that provides a framework for the integration and sharing of observational data from National Meteorological and Hydrological Services and other sources. It also should be noted that weather is not stationary, and accurate weather forecasts depend on having global observations for accurate initialization of numerical weather forecast models.

CORF notes that EESS (active) instruments that use radar (in other frequency bands) to measure ocean topography (sea-surface height and waves), sea ice, and precipitation typically also include an EESS (passive) sensor in the 23.6-24.0 GHz band. This sensor measures the total atmospheric water vapor amount and is used to correct the refraction-induced path delay in the radar signal. CORF notes that these altimeters also provide a substantial contribution to solid earth (geoid) science.³

CORF also notes that microwave radiometer measurements at or near 23.8 GHz constitute one of the longest continuous records of atmospheric-integrated water vapor content measured from space, starting with the European Space Agency's ERS-1 mission in 1991. The development, deployment, and operation of these satellite missions, together with their long-term calibrated and validated climate data records, represent a significant investment and commitment by numerous national governments and international agencies. Furthermore, many private commercial companies use these vital measurements for weather forecasting and are also expanding into the commercial EESS sector.

³ See the WMO Observing Systems Capability Analysis and Review Tool (OSCAR), "List of Mission Types: Radar Altimetry," <https://space.oscar.wmo.int/observingmissions/view/13>, accessed 2/11/2024, for more details.

TABLE 1: Selected Satellites: Instruments for Observation at 23.6-24.0 GHz

Agency Satellite: Instrument	Band Center Frequency	Bandwidth	Years
NASA AQUA: AMSU-A ⁴	23.8 GHz	270 MHz	2002-2026+
NASA GPM: GMI ⁵	23.8 GHz	400 MHz	2014-2032
NASA JASON-1/2/3: JMR/AMR ⁶	23.8 GHz	400 MHz	2001-present
NOAA-15/16/17/18/19: AMSU-A ⁷	23.8 GHz	270 MHz	1998-present
NOAA SNPP, NOAA-20 (JPSS-1), NOAA-21 (JPSS-2): ATMS ⁸	23.8 GHz	270 MHz	2011-2030+
EUMETSAT MetOp-A/B/C: AMSU-A ⁹	23.8 GHz	270 MHz	2006-2027+
JAXA ADEOS: AMSR, AQUA: AMSRE, GCOM-W: AMSR2 ¹⁰	23.8 GHz	400 MHz	2002-present
CNES SARAL: AltiKa ¹¹	23.8 GHz	200 MHz	2013-present
ESA Sentinel-3 A,B,C,D: MWR ¹²	23.8 GHz	200 MHz	2016-2038+
NASA ISS COWVR: COWVR ¹³	23.8 GHz	475 MHz	2021-present
JAXA GOSAT-GW: AMSR3	23.8 GHz	400 MHz	2024-2031+
NOAA JPSS-3/4: ATMS ¹⁴	23.8 GHz	270 MHz	2028-2041+
DMSP: WSF-M1/M2 ¹⁵	23.8 GHz	370 MHz	2024-2035+
NASA SWOT: MW radiometer ¹⁶	23.8 GHz	400 MHz	2022-2026+
EUMETSAT EPS-SG A1/A2/A3: MWS	23.8 GHz	270 MHz	2025-2046+
EUMETSAT EPS-SG B1/B2/B3: MWI ¹⁷	23.8 GHz	400 MHz	2025-2047+

NOTE: Italics denote sensors yet to be launched. + denotes extended nominal lifetime.

⁴ WMO OSCAR, "Instrument: AMSU-A," https://www.wmo-sat.info/oscar/instruments/view/amsu_a.

⁵ NASA, "GMI Overview," <https://gpm.nasa.gov/missions/GPM/GMI>.

⁶ NASA Jet Propulsion Laboratory, Physical Oceanography Distributed Active Archive Center, "Jason 3: Instruments," <https://podaac.jpl.nasa.gov/JASON3?tab=instruments>.

⁷ NOAA National Climatic Data Center, "AMSU Brightness Temperature," <https://www.ncdc.noaa.gov/cdr/fundamental/amsu-brightness-temperature>.

⁸ NASA Goddard Space Flight Center, "JPSS-1 ATMS Level 1B Brightness Temperature Version 2 Data Release," updated 2/18/21, https://disc.gsfc.nasa.gov/datasets/SNDRJ1ATMSL1B_2/summary.

⁹ EUMETSAT, "AMSU-A," <https://www.eumetsat.int/amsu-a>.

¹⁰ Japan Aerospace Exploration Agency, "About Global Change Observation Mission – Water "SHIZUKU" (GCOM-W)," https://global.jaxa.jp/projects/sat/gcom_w/.

¹¹ European Space Agency (ESA), "SARAL," <https://earth.esa.int/web/eoportal/satellite-missions/s/saral>.

¹² ESA, "MWR," <https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-3-altimetry/instrument/mwr>.

¹³ WMO OSCAR, "Instrument: COWVR," <https://www.wmo-sat.info/oscar/instruments/view/cowvr>.

¹⁴ NOAA, "Advanced Technology Microwave Sounder (ATMS)," <https://www.jpss.noaa.gov/atms.html>.

¹⁵ ESA, "WSF-M (Weather System Follow-on - Microwave) Satellite," <https://www.eoportal.org/satellite-missions/wsf-m>.

¹⁶ NASA, "SWOT Payload," <https://swot.jpl.nasa.gov/resources/91/swot-payload/>.

¹⁷ EUMETSAT, <https://www.eumetsat.int/eps-sg-microwave-imager>.

II. Protection of Passive Services at 23.6-24.0 GHz.

As the NPRM recognizes, important and extensive Earth remote sensing research is performed with passive scientific instruments at 23.6-24.0 GHz.¹⁸ It is critical that such observations be protected as much as possible from harmful interference in the form of OOBES from UMFUS operations. Such protection, particularly for EESS/Remote Sensing, was the core intent of the modification of Res. 750 at the World Radiocommunication Conference 2019 (“WRC-19”) regarding 23.6-24.0 GHz. The limits adopted in Res. 750 were compromise levels intended to provide substantial, if not comprehensive, protection of this vital Earth remote sensing capability.

It is important to note that the 23.6-24.0 GHz band is protected by RR 5.340, where “all emissions are prohibited.” Notwithstanding that, as a practical matter, the starting point for any consideration of interference into EESS passive bands is the International Telecommunication Union (“ITU”) Radiocommunication Sector (“ITU-R”) Recommendation RS.2017, which establishes a limit of –166 dBW in 200 MHz for the

¹⁸ While the focus of this proceeding is primarily on protection of the Earth Exploration Satellite Service (“EES”), the Radio Astronomy Service (“RAS”) has a co-primary allocation at 23.6-24.0 GHz. This band includes one of the most important sets of spectral lines: ammonia at rest frequencies 23.694, 23.723, and 23.870 GHz. Observed in combination, this set of lines serves as a probe of both gas kinetic temperature and density in regions of active star formation, providing vital insight into that process. In addition, radio astronomy continuum observations in the 23.6-24.0 GHz band are used to distinguish the spectral signatures of cosmic synchrotron emission from high-energy electrons, free-free emission (Bremsstrahlung), and thermal emission. As designated in International Telecommunication Union (“ITU”) Radiocommunication Sector (“ITU-R”) Recommendation RA.314-10, the 23.6-24.0 GHz band is one of the preferred frequency bands for radio continuum observations. ITU-R Recommendation RA.314-10 also designates 23.61-23.71 GHz, 23.64-23.74 GHz, and 23.79-23.89 GHz as the suggested minimum bands for observations of the three ammonia lines noted. The focus of CORF’s comments herein will be on protection of EESS observations. However, this does not negate the need to protect RAS observations at 23.6-24.0 GHz. As discussed more fully in CORF’s prior comments, adoption of the out-of-band emission limits of Resolution 750 (Rev. WRC-19) results in the requirement for separation distances of 60-70 km between fixed and mobile Upper Microwave Flexible Use Service (“UMFUS”) stations and protected RAS observatories, in order to achieve ITU-R Recommendation RA.769 levels for a single isotropic emitter. The separation requirement is particularly important for maintaining observational capability at facilities in densely populated regions such as the Haystack Observatory located within the crowded northeast U.S. population corridor.

23.6-24.0 GHz band, to be met over 99.99 percent of a 10,000,000 km² area. CORF notes that the limits specified in ITU-R Resolution 750 (Rev. WRC-19), when applied to likely International Mobile Telecommunications (“IMT”) implementations, and taking into consideration typical characteristics of orbiting EESS sensors (described in ITU-R Recommendation RS.1861), fail to meet this criterion, particularly when considering the aggregate interference from the vast multiplicity of transmitters that are inherent to the nature of IMT deployments. In CORF’s view, the OOB limits recommended by others going into WRC-19, including the European Commission (–42 dBW in 200 MHz) or those of the World Meteorological Organization (“WMO”) (–55 Dbw in 200 MHz), are more in line with the degree of OOB attenuation required to meet ITU-R Recommendation RS.2017 interference thresholds.¹⁹

For example, the AMSR2 instrument on the GCOM-W1 spacecraft (the successor to NASA’s AMSR-E instrument launched on the Aqua mission in 2002) measures natural black-body emission signals over a 400 MHz-wide region of the spectrum at 24 GHz with 14 x 14 km pixels. Thermal emission from one such pixel over dry land at 300 K (80°F) in this band totals to only ~26 W across this ~200 km² pixel. This 26 W is emitted in all directions, and the AMSR2 instrument receives only a fraction of a trillionth of that power. The ITU-R Recommendation RS.2017 interference threshold equates to requiring that there should be no perturbations (e.g., from RFI) greater than 4 mW total emission across this entire pixel. This requirement enables EESS (passive) measurements to be made with an accuracy of 0.05 K brightness temperature (~0.09°F), which is considered

¹⁹ The mismatch is likely greater for proper protection of RAS, for which more stringent interference thresholds are specified in ITU-R Recommendation RA.769.

sufficient to provide accurate weather forecasts and reliable quantification of potential signatures of climate change (which are of order of one or two degrees per century). The Res. 750 limits of -35 dBW in 200 MHz for mobile devices²⁰ equates to 0.4 mW per device, only a factor of 10 below the ITU-R Recommendation RS.2017 threshold. Thus, even assuming somewhat directional beams from mobile devices, it is clear that deployment of thousands of such devices in urban areas (likely an underestimate) will exceed this threshold. In sum, while the OOB protection levels established in Res. 750 necessarily provide some level of protection for remote sensing, it appears to be insufficient for complete protection of EESS, and thus an even higher level of protection would have been preferable.

Nevertheless, CORF urges the Commission to continue its plans to adopt the Res. 750 OOB levels as a critical step for preserving remote sensing capability. However, it notes that a risk remains that this will prove insufficient to fully protect all existing EESS (passive) capability.

In para. 17, the NPRM seeks comment on whether it would be necessary to apply emissions limits stricter than -13 dBm/MHz to fixed operations in the 24 GHz band. CORF urges the Commission to keep the broad purpose of OOB standards generally, and Res. 750 specifically, in mind in this proceeding. The broad purpose is to protect passive services from OOB. It is counterproductive to protect passive uses from OOB from *mobile* service equipment, but not from equipment used for UMFUS *fixed* services. Accordingly, CORF recommends that a rigorous OOB standard apply to all

²⁰ Note that this limit only applies to devices deployed after September 1, 2027, a less restrictive -29 dBW in 200 MHz limit applies currently.

UMFUS equipment operating at 24 GHz: UMFUS fixed point-to-point and point-to-multipoint equipment, as well as mobile equipment. CORF recognizes that arguments can be put forward invoking the differences in antenna directivity and pointing involved in these applications, but questions how well they can be quantified in the presence of scattering toward the sky from ground clutter.

The NPRM states that “numerous point-to-point microwave links deployed by non-federal and federal operators in the 21.2-23.6 GHz band (which has propagation characteristics similar to the 24 GHz band and is immediately adjacent to the 23.6-24.0 GHz passive band) operate with the same unwanted emissions limits that apply under the UMFUS rules,” and seeks comments on whether these existing deployments have caused harmful interference to passive sensors in the 23.6-24.0 GHz band. At present, CORF cannot verify whether or not these point-to-point links have caused harmful interference to passive sensors at 23.6-24.0 GHz, but observations at these frequencies have shown characteristics consistent with RFI, as shown in Figure 1. Moreover, although strong interference is recognizable and can be excised from further analysis (but at the cost of fewer measurements for both the EESS and the Radio Astronomy Service [“RAS”]), weak levels of interference are often subtle and thus provide corrupted information, undermining the reliability and value of, for example, weather forecasting and climate models. Given the hopes of both the Commission and industry for the widespread use of UMFUS equipment to provide 5G services, there will likely be a significant difference between the impact from the existing limited number point-to-point links spread across the United States, and the potentially millions of UMFUS devices in the future. Furthermore, the fact that fixed UMFUS operations will not be individually

licensed distinguishes them from the individually licensed status of most links in the fixed microwave services and will make the remediation of interference from the UMFUS operations difficult, if not impossible.

In para. 18, the NPRM seeks comments on an industry proposal that indoor small-cell systems be exempt from the Res. 750 limits. CORF recommends against carving out such an exemption, particularly for low-cost devices that may be deployed in large numbers. CORF agrees with the Commission's observation that these devices typically operate at lower power, making it easier to achieve the Res. 750 limit. As noted in the NPRM, emissions from these devices would be shielded by building attenuation, and ITU-R Recommendation P.2109-2 predicts a median building entry loss of approximately 20 dB at 24 GHz for buildings constructed of traditional materials, but with a significant probability for attenuation as low as a few decibels. Moreover, further offsetting factors include the density of access point deployment required to achieve coverage within a given building and the positioning of indoor access points to cover adjacent areas such as balconies and patios. Finally, as noted previously, the Res. 750 limits already exceed limits that would be obtained taking ITU-R Recommendation RS.2017 as a starting point. At best, for what could become a ubiquitous class of devices, building entry loss serves to reduce emissions to a lower but not necessarily acceptable level. If, however, the Commission authorizes such use, then it should take additional steps to ensure that such devices are in fact used solely indoors, such as including a requirement on the devices and/or on the packaging for the devices.

At para. 25, the NPRM notes that the UMFUS rules currently permit equipment manufacturers the flexibility of demonstrating compliance with the OOB limits by using

either a total radiated power (“TRP”) or conductive methodology when obtaining equipment certification, and it seeks comments on whether to allow continued use of both of these methodologies. CORF notes that many 24 GHz devices will not have clean access to an antenna port, and that even those devices that do may radiate unintentionally from other parts of the system. Accordingly, CORF recommends use of the TRP methodology be required for the equipment certification process.

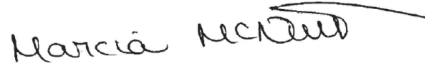
III. Conclusion.

CORF acknowledges the Commission’s recognition in the NPRM of the critical importance of protecting the 23.6-24.0 GHz band, which is reserved for passive scientific use, from OOB of UMFUS operations at 24.25-24.45 GHz and 24.75-25.25 GHz. In particular, CORF appreciates the Commission’s proposal to adopt the Res. 750 limits for equipment operating in these bands and urges it not to relax those limits. Indeed, in CORF’s view, as noted above, even with the Res. 750 limits, there is every reason to expect levels of RFI that will render a non-negligible fraction of the EESS (passive) observations unusable, particularly over densely populated areas. The Commission should use the information provided herein to enact other more specific OOB protections, including requiring Res. 750-based OOB standards for both fixed and mobile 24 GHz equipment, not exempting indoor small cell systems from Res. 750-based OOB standards, and using TRP methodology for making equipment certifications.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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